TITLE

Predicting injury among older and younger elite football players using training load metrics and the acute:chronic workload ratios

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Predicting injury among older and younger elite football players using training load metrics and the acute:chronic workload ratios

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This Research Project is submitted as partial fulfilment of the requirements for the degree of Master of Science, St Mary's University

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Predicting injury among older and younger elite football players using training load metrics and the acute:chronic workload ratios

Abstract

The study used training and competition load metrics to investigate injury risk amongst elite youth (17.3 ± 0.5 years) and senior footballers (25.5 ± 5.3 years). The two groups were compared using various accumulative loads and a training stress balance (TSB). Several variables were investigated; duration, total distance, high-speed distance and number of accelerations performed. Workload and injury incidence data were collected over a 15-week, in-season period, and split between the youth and senior participants. Z-scores were used to classify the loads into five categories; very low, low, moderate, high and very high. Binary logistical regressions were used to identify any relationships between injury risk and the GPS derived variables. When the TSB for the number of accelerations was 0.57-1.04; or a total distance of 103800-138899 m occurred over 4 weeks, there was increased risk of injury in senior participants. There was also an increased risk in youth participants when training duration of >25:15:00 over 2 weeks occurred; or the TSB for high-speed distance was <0.40; or 0.93-1.47. Increased risk of non-contact injury in the senior participants occurred when high-speed distance was 1705.0-5543.9 m over a 4-week period; or when the TSB for the total distance was 1.53-2.01; or when the TSB for the number of accelerations was 0.57-1.52. Increased risk is apparent in the youth participants when 30–55 accelerations occurred over 1 week; or 110-151 over 2 weeks; or when the TSB for high-speed distance was <0.40; or 0.93-1.47. High TSB values did not predict injuries. Higher workloads in youth participants did not increase the likelihood of injury. Low loads appear to predict injury more significantly than high loads.

Keywords; Training load monitoring, Football, Injury prevention, Youth athletes, Training stress balance

Introduction

The Elite Player Performance Plan (EPPP) was introduced by the English Football Association to create more 'home grown players' and increase the standard's in the professional game (The Premier League, 2011). Players aged 16-18 years are required to train for a minimum of 12 hours per week, excluding competition or any additional 'off-field training', such as strength development or tactical analysis (The Premier League, 2011).

Injuries are extremely common in football with the majority involving the lower limbs (Ekstrand, Hagglund, & Walden, 2009). A study of the injury records of senior players from 51 elite clubs in Europe indicated that injuries occurred most commonly to the hamstrings (0.92/1000 hours), quadriceps (0.41/1000 hours), adductors (0.57/1000 hours) and calf muscles (0.31/1000 hours) in both training and competitive game time (Ekstrand et al., 2009). This equates to an average loss of 223 days and 37 games per season for a 25-player squad.

For many players, full time professional football results in a significant increase in both the intensity and volume of training and competition, which places greater physical demands on the body (Van Beijsterveldt, Stubbe, Schmikli, Van De Port, & Backx, 2015). This additional demand also appears to be increasing season by season based on a study that compared English Premier League games from the 2006/07 and 2012/13 seasons (Barnes, Archer, Hogg, Bush, & Bradley, 2014). During that period there was an increase of approximately 2 % in the total distance covered in competitive games (10679 ± 956 m vs. 10881 ± 885 m). More interestingly, there were significant differences in the high intensity distance covered (approximately 30 %, 890 ± 299 m vs. 1151 ± 337 m), and sprint distance (approximately 35 %, 232 ± 114 m vs. 350 ± 139 m). This additional physical demand increases the risk of injury due to the high volume or intensity of the various stressors placed on the body, specifically acting on soft tissues in the lower limbs. However, this is not the only reason and other factors such as injury history and the training stress balance (TSB) contribute to injury.

Senior players often possess a longer history of injuries due to the increased exposure to training and competition (i.e. training age). Indeed, previous injuries are seen as the best indicator of future injuries (Van Beijsterveldt et al., 2015). Hagglund, Walden and Ekstrand (2006) found that players who suffered a hamstring, groin or knee joint injury were 2-3 times more likely to suffer a reoccurrence of the injury the following season. The same study found players with 5 or more previous injuries were 5.2 times more likely to suffer further injury (Hagglund, Walden, & Ekstrand, 2006). Reductions in $\dot{V}O_{2max}$ of 7-12 % per decade; and lean muscle mass, together with increases in body fat occur as part of an athletes natural aging process (Foster, Wright, Battista, & Porcari, 2007; Hawkins & Wiswell, 2003). This reduces the ability of athletes to perform at the same volume and intensity as earlier in their careers, and places additional demands on the body that may increase the risk of injury in this population.

A recent consensus statement highlights the need for load monitoring to take place in sports, and discusses the importance of monitoring from both performance and injury prevention perspectives (Bourdon et al., 2017). Several studies have investigated the relationship between training load and injuries, illness and soreness, and discovered that all 3 outcomes can occur within a number of weeks after an increased load is placed on the body (Drew & Finch, 2016; Jaspers, Brink, Probst, Frencken, & Helsen, 2017).

Research conducted by Gabbett and colleagues also supports the work of Drew and Finch (2016) in several studies that consider the differences in the acute and chronic training loads, also known as the TSB (Blanch & Gabbett, 2015; Hulin et al., 2014; Hulin, Gabbett, Lawson, Caputi, & Sampson, 2015; Malone et al., 2017; Windt & Gabbett, 2016). When an accelerated training load is experienced without developing a prior tolerance, structures will break down and lead to soft tissue injuries to the muscles, ligaments and tendons around the ankle, knee and hip joints (Drew & Finch, 2016).

It has been shown that there is a significantly higher risk of injury where the acute training load (7-day load), is significantly greater than the chronic load (28-day load). A study in football using a rate of perceived exertion scale (RPE) method to categorise load, and the TSB to detect injury risk, found that a difference of 1.00-1.25 was the optimal acute load in comparison to the chronic load in order to prevent injury to the athlete (Malone et al., 2017). Research conducted in rugby league found an increased risk of injury when the chronic load was high and there was a value of >1.5, or when the chronic load was low and there was a value of >2.0, using the total distance as an indicator of load (Hulin et al., 2015). Hulin et al. (2014) found a similar result in cricket, using the number of fast-balls bowled as the indicator of load. TSB values >1.5 increased the risk of injury by 2-4 times within the next 7 days. However, while values >1.5 may lead to increased injury risk, it is possible that higher values may also improve performance by creating greater physical adaptations. Unfortunately, there appears to be no research that helps to understand what the optimal TSB is for these adaptations.

The above mentioned studies were conducted in senior athletes (Hulin et al., 2014, 2015; Malone et al., 2017). Similar findings were found in studies involving 16-18 year old elite footballers when the acute training loads were significantly higher than the average chronic load (Bowen, Gross, Gimpel, & Li, 2016). Bowen and colleagues found there was a non-contact injury incidence of 6.9/1000 hours of training and competition, with the majority occurring to the ankle (2.1/1000 hours). Significant increases in non-contact injuries were found when distances of between 3502-5120 m were covered at high speeds (total distance covered >20 km/h) over a 4-week period. Increases also occurred when ≥9254 accelerations were performed over a 3-week period (Bowen et al., 2016). Conversely, injury risk was significantly reduced when 744-2861 accelerations were performed over a 3-weekly period; or during a 1-weekly period when the total distance was <8812 m; or the high speed running distance was <756 m. When observing the TSB, increased injury risk was discovered in total distance, high-speed running distance and accelerations when the acute load was higher than the chronic load (Bowen et al., 2016).

To date, there are a limited number of studies comparing the injury risks between senior and elite youth footballers using a joint study approach. One recent study comparing senior and u19 players in the Danish Football Leagues found that there were significant differences in the total distance, number of accelerations and decelerations in a game, with the u19 players showing higher totals in each category (Vigh-Larsen, Dalgas, & Andersen, 2017). However, this study did not compare the injury characteristics of the players, or consider any TSB data.

The purpose of this study was to identify the different training load-based predictors of injury among both elite youth and senior professional footballers. Other studies have investigated injury risk in both populations but never compared the two, despite the fact that the injury mechanism might differ between groups (Bowen et al., 2016; Van Beijsterveldt et al., 2015). Conducting the study at the same club where the approach to training and competition broadly shares a similar philosophy will help to eliminate any changes that occur due to differences in performance.

Data in respect of total distance, high speed running distance, accelerations and training duration was collected and compared in 1-weekly, 2-weekly, 3-weekly and 4-weekly accumulative loads, together with the TSB replicating previous research (Bowen et al., 2016; Hulin et al., 2015). The exact nature of the injuries was recorded, and also whether they occurred in contact or non-contact situations.

Having regard to the above, the hypothesis for this research was;

1. Higher TSB scores would increase the risk of injury in all participants
2. High and very high accumulative loads would result in injury in all participants
3. Elite youth footballers would be exposed to a higher risk of injury due to the greater physical demands placed on them

Method

Participants

Data were collected from senior professional (n = 23, age: 25.5 ± 5.3 years, stature: 179.8 ± 6.4 cm, body mass: 83.0 ± 5.1 kg) and elite junior footballers (n = 12, age: 17.3 ± 0.5 years, stature: 180.1 ± 5.2 cm, body mass: 73.6 ± 4.8 kg) from the same English Football League club. All participants trained full time and competed in either the English Football League or the North East Youth Alliance Under-18 League. Ethical approval was granted from the Ethics Sub-Committee at St Mary's University, Twickenham on the 13th January 2017. Data were collected over a 15-week period commencing 23rd January 2017. Written informed consent/assent forms were obtained prior to any data collection from all participants and their guardians where necessary.

Procedures

Workload was collected using data derived from Global Positioning System (GPS) monitors (Team Pro v.20160916, Polar, Finland). The units sampled at a rate of 10 Hz for the GPS and 200 Hz for the accelerometer. Participants were required to wear a chest strap with a small sensor attached (39 g; 36 mm x 68 mm x 13 mm). The monitors were attached immediately prior to, and removed straight after, all field-based training and competitions. The Participants wore the same units throughout the duration of the study. The methods used to gather the data are common practice in sport, and were similar to those used in previous research (Bowen et al., 2016; Hulin et al., 2014, 2015). Team averages were used from the training sessions to identify and isolate any discrepancies in the data arising from technical faults, such as GPS signal failure. Where participants failed to wear the monitor (n = 87), their average data were used relative to the duration of their participation (3 games minimum). The TSB was under constant review throughout the data collection period, and the training loads were adjusted when necessary to help prevent or reduce the number injuries, by limiting the TSB to less than 1.5 based on previous research.

The variables collected for this study were the Total Distance (TD; total distance covered), High-Speed Running Distance (HSD; total distance covered above 19 km/h), Accelerations (ACC; number of increases in velocity above 3 m/s^2) and Duration (DUR; the time spent training and competing), in line with similar studies that calculated workload and injury risk in football (Bowen et al., 2016). The 'speed zones' on the GPS system used at the club were fixed with the highest zone set at 19 km/h.

Definition of injury

Injuries were determined and diagnosed by the Head Physiotherapist, the Head Academy Physiotherapist and the Club Doctor in line with the consensus statement on defining injuries (Fuller et al., 2006). The circumstances of the injury were recorded based on whether they occurred in training or competition, and if they were contact or non-contact in the mechanism. Contact injuries were defined as an injury that occurred due to external forces resulting in trauma, whereas non-contact injuries occurred when no external forces were present.

Data analysis

Data were initially separated into 2 groups; the elite youth players (born after 31/08/1998) and the senior players (born before 01/09/1998). The data for the respective groups was then split into 1-weekly, 2-weekly, 3-weekly and 4-weekly loads. Z-scores were used to split the loads into very-low (VL), low (L), moderate (M), high (H) and very high (VH) classifications (Table 1.).

Table 1. Classification of boundaries for all variables measured

	Z Scores	1 weekly	2 weekly	3 weekly	4 weekly	TSB
Duration (hr:min:sec)						
Very Low	≤ 1.00	≤ 4:31:00	≤ 9:30:00	≤ 14:47:59	≤ 20:06:59	≤ 0.61
Low	-0.99 - 0.00	4:30:59 - 7:18:07	9:29:59 - 15:17:29	14:48:00 - 21:36:59	20:07:00 - 28:41:59	0.61 - 1.04
Moderate	0.00 - 0.99	7:18:08 - 10:13:35	15:17:30 - 19:25:59	21:37:00 - 28:21:02	28:42:00 - 37:21:59	1.05 - 1.46
High	1.00 - 1.99	10:13:35 - 13:00:59	19:26:00 - 25:14:59	28:21:03 - 35:09:59	37:22:00 - 45:57:59	1.47 - 1.86
Very High	≥ 2.00	≥ 13:01:00	≥ 25:15:00	≥ 35:10:00	≥ 45:48:00	≥ 1.87
Total Distance (m)						
Very Low	≤ 1.00	≤ 14549	≤ 32099	≤ 50999	≤ 69299	≤ 0.58
Low	-0.99 - 0.00	14550 - 26449	32100 - 52499	51000 - 78399	69300 - 103799	0.59 - 1.05
Moderate	0.00 - 0.99	26450 - 38399	52500 - 72899	78400 - 105999	103800 - 138899	1.06 - 1.52
High	1.00 - 1.99	38400 - 49999	72900 - 92999	106000 - 134499	138900 - 174599	1.53 - 2.01
Very High	≥ 2.00	≥ 50000	≥ 93000	≥ 134500	≥ 174600	≥ 2.01
High Speed Running distance (m)						
Very Low	≤ 1.00	n/a	≤ 149.9	≤ 964.9	≤ 1704.9	≤ 0.40
Low	-0.99 - 0.00	0 - 1438.9	150.0 - 2881.9	965.0 - 4480.9	1705.0 - 5543.9	0.41 - 0.92
Moderate	0.00 - 0.99	1439.0 - 3199.9	2882.0 - 5664.9	4481.0 - 7826.9	5544.0 - 9449.9	0.93 - 1.47
High	1.00 - 1.99	3200.0 - 4999.9	5665.0 - 8399.9	7827.0 - 11099.9	9450.0 - 13199.9	1.47 - 2.07
Very High	≥ 2.00	≥ 5000	≥ 8400	≥ 11100.0	≥ 13200.0	≥ 2.08
Accelerations (Au)						
Very Low	≤ 1.00	≤ 29	≤ 67	≤ 106	≤ 146	≤ 0.56
Low	-0.99 - 0.00	30 - 55	68 - 109	107 - 161	147 - 214	0.57 - 1.04
Moderate	0.00 - 0.99	56 - 81	110 - 151	162 - 217	215 - 283	1.05 - 1.52
High	1.00 - 1.99	82 - 108	152 - 194	218 - 274	284 - 352	1.53 - 1.99
Very High	≥ 2.00	≥ 108	≥ 194	≥ 275	≥ 353	≥ 2.00

The second part of the data analysis calculated the TSB value by dividing the acute load (1-weekly load) by the chronic load (4-weekly load). Values >1 mean that the acute load is higher than the chronic load, whereas values <1 mean the acute load is lower. The scores were divided into VL-VH groups in the same manner as the 1-4 weekly accumulative loads (Table 1.).

Statistical analysis

IBM SPSS Statistics V.22.0 software was used to show significance in the data (significant at $p<0.05$). Injury incidence is reported as the number of injuries per 1000 hours of training and competition. Independent samples T tests were used to determine if there were any statistically significant differences between the senior and junior participants' datasets. A binary logistic regression model was used to determine if any of the independent variables related to injury risk, and also if there was any relationship to non-contact injury. There were two options of outcome; injured and non-injured. The TSB values and accumulated workloads were independently modeled as predictor variables.

Results

Independent samples T tests were used to compare the youth and senior participants; to determine whether there were any differences between the average DUR, TD, HSD and ACC over 1-weekly, 2-weekly, 3-weekly and 4-weekly loads, and also using the TSB of each variable. No differences were identified when comparing the TSB values (Figure 1.), but, differences were found in all of the accumulative loads when comparing the youth and senior athletes' DUR (Figure 2.; $p = 0.000$). Differences were also found when comparing the TD (2-weekly $p = 0.013$; 3 & 4-weekly $p = 0.000$), HSD (2-weekly $p = 0.041$; 3-weekly $p = 0.008$; 4-weekly $p = 0.001$) and ACC (2-weekly $p = 0.006$; 3 & 4-weekly $p = 0.000$), 2-weekly, 3-weekly and 4-weekly accumulative loads (Figure 3,. Figure 4. & Figure 5.).

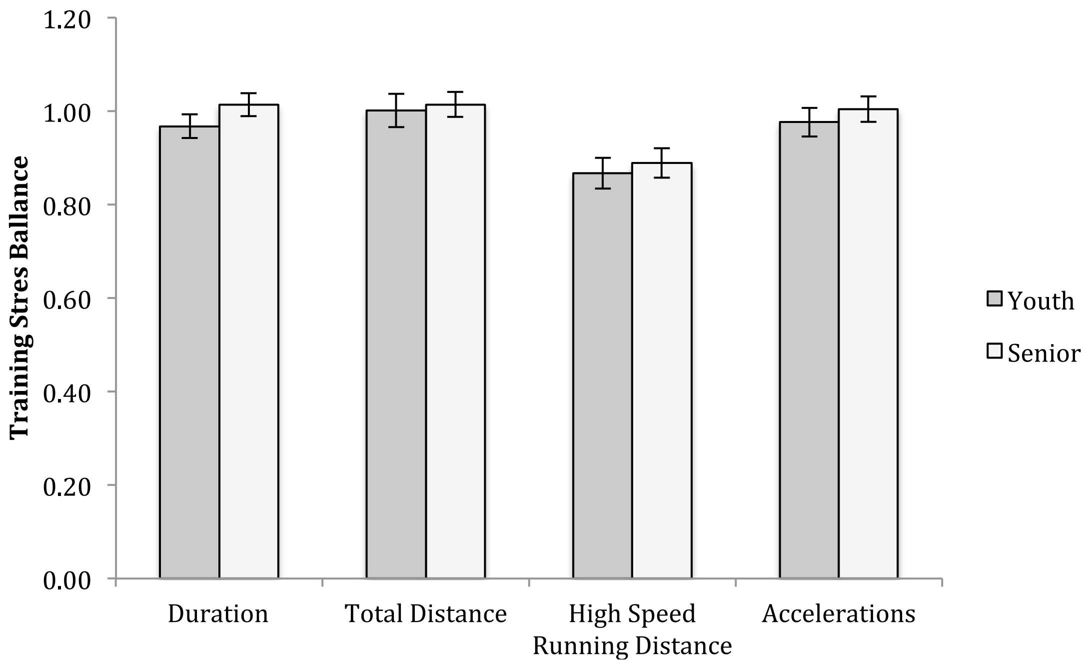

Figure 1. A comparison of the TSB for youth and senior participants

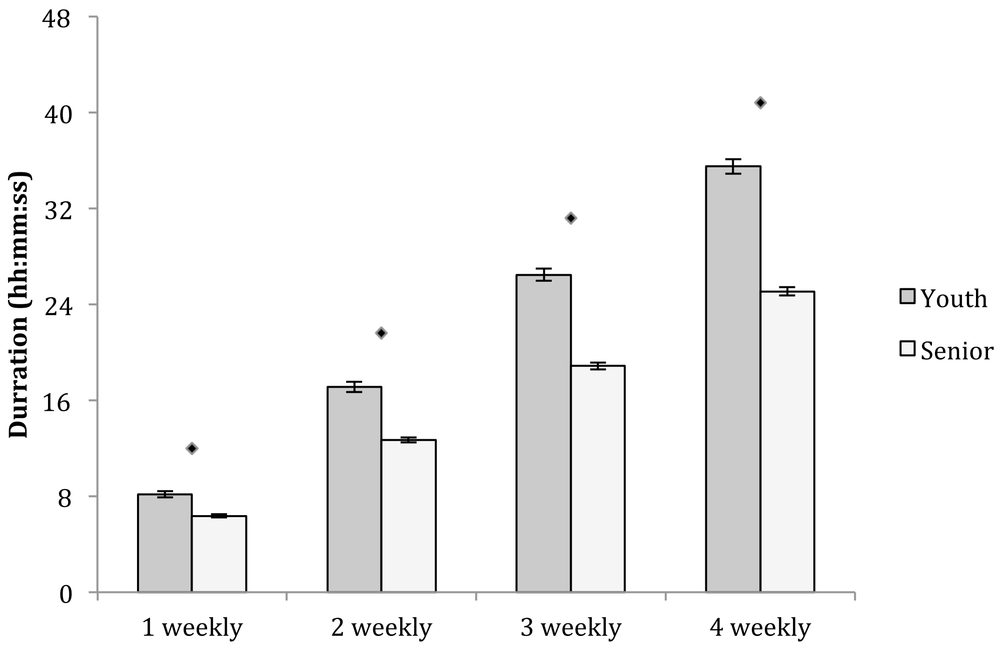

Figure 2. The difference in duration per week between youth and senior participants

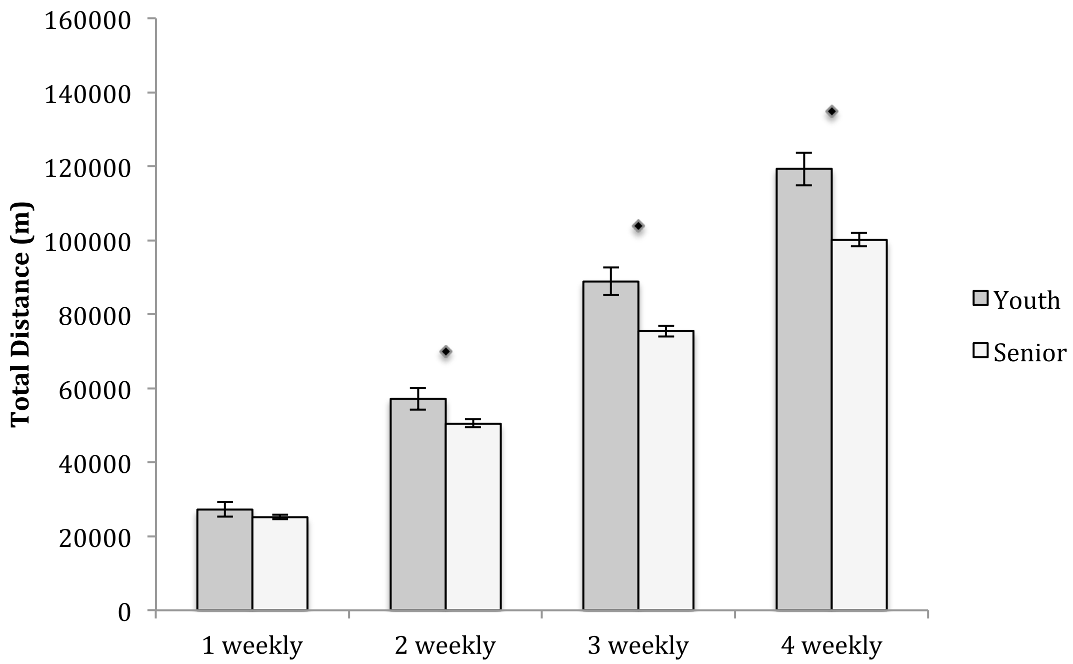

Figure 3. The difference in the total distance covered per week between youth and senior participants

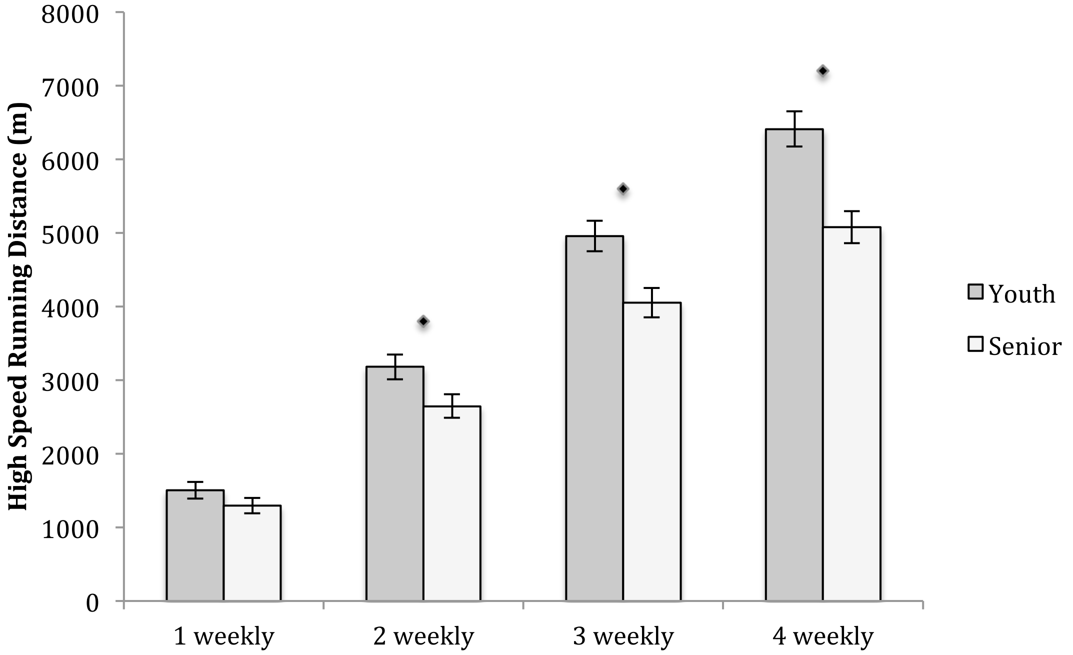

Figure 4. The difference in high speed running distance covered per week between youth and senior participants

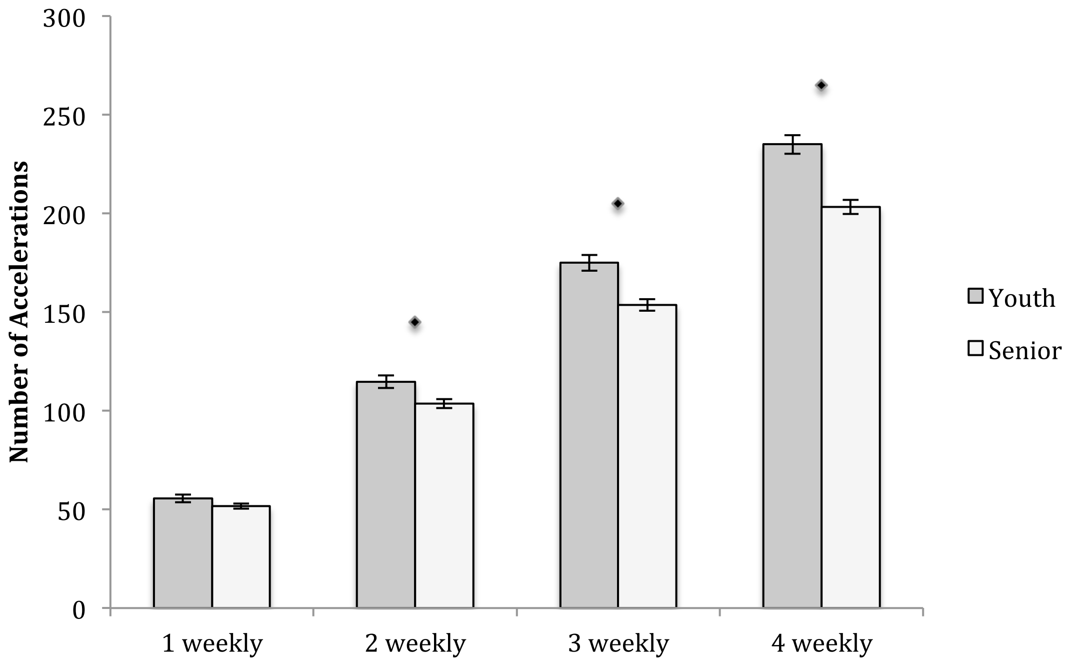

Figure 5. The difference in the number of accelerations per week between youth and senior participants

In total there were 35 injuries in the testing period; 21 occurred to senior and 14 to junior athletes (Table 2.). 62.9 % of all injuries occurred in non-contact situations (4.6/1000 hours) with the other 37.1 % in contact. The rate of non-contact injuries was higher in the youth athletes (5.4/1000 hours) compared to senior athletes (4.1/1000 hours). 48.6 % of injuries occurred in each of the training and competition conditions, with the other 2.8 % occurring in other situations. The majority of contact injuries occurred in competition (3.5/1000 hours). No difference was found between the number of injuries or non-contact injuries in either group.

Muscle strains were the most common injury type across both groups and all occurred in non-contact situations (4.4/1000 hours). More muscle strains occurred in the senior athletes (4.6/1000 hours), in comparison to the youth athletes (4.1/1000 hours), even though more non-contact injuries occurred in the youth athletes.

Table 2. Injury incidence per 1000 hours

	Youth athletes		**Senior athletes**		**Total**	
(/1000 hours)	**Non-contact 6.1**	**Contact 3.4**	**Non-contact 5.9**	**Contact 3.7**	**Non-contact 6.0**	**Contact 3.5**
Activity						
Competition	0.7	3.4	1.4	3.6	1.1	3.5
Training	5.4	0.0	4.1	0.0	4.6	0.0
Other	0.0	0.0	0.5	0.0	0.3	0.0
Type						
Muscle strain	4.1	0.0	4.6	0.0	4.4	0.0
Ligament sprain	0.7	0.0	0.9	1.4	0.8	0.8
Fracture/ dislocation	0.0	0.7	0.0	0.0	0.0	0.3
Haematoma/ contusion	0.0	2.0	0.0	1.8	0.0	1.9
Laceration	0.0	0.7	0.0	0.0	0.0	0.3
Other	1.4	0.0	0.5	0.5	0.8	0.3

Binary logistical regression models were used for both groups to determine whether injury could be predicted using the TSB, 1-weekly, 2-weekly, 3-weekly and 4-weekly loads for TD, HSD, ACC and DUR. When these models were tested against a constant only model the results showed a statistical significance (Senior, $\chi 2 = 13.13$, $p < 0.05$ with df = 4; Youth $\chi 2 = 8.57$, $p < 0.05$ with df = 2). Prediction success overall was 91.7 % for the youth model and 94.2 % for the senior model. An insignificant value is derived from the Hosmer and Lemeshow test ($p > 0.05$), proving that both the models were a good fit.

The model showed that a TD of 103800-138899 m over 4 weeks ($p = 0.22$), or ACC with a TSB of 1.57-1.04 ($p = 0.04$) significantly increased the risk of injury in the senior participants. In the youth participants a DUR of >25:15:00 over 2 weeks significantly increased the risk of injury ($p = 0.008$). There was an increased risk when the TSB for HSD was <0.40 ($p = 0.006$) or 0.93-1.47 ($p = 0.003$).

A second pair of binary logistical regressions were used to determine whether the same variables could predict non-contact injuries. When these models were tested against a constant only model the results showed statistical significance (Senior, $\chi 2 = 8.48$, $p < 0.05$ with df = 4; Youth $\chi 2 = 5.73$, $p < 0.05$ with df = 4). Prediction success overall was 95.1 % for the youth model and 96.7 % for the senior model. An insignificant value is derived from the Hosmer and Lemeshow test ($p > 0.05$), proving that both the models were a good fit.

The model investigating whether any of the variables in the senior participants could predict non-contact injury found increased risk when HSD was between 1705.0-5543.9 m over a 4-week period ($p = 0.009$). Injury risk was also increased when the TSB for the TD was 1.53-2.01 ($p = 0.007$). The senior model also found that ACC predicted non-contact injuries when the TSB was 0.57-1.04 ($p = 0.037$), or 1.05-1.52 ($p = 0.041$).

The model found increased risk in both ACC and HSD when considering whether any of the variables in the youth participants could predict non-contact injury. Increased risk is apparent when 30–55 ACC over 1 week ($p = 0.033$), or 110–151 ACC over 2 weeks occurs ($p = 0.027$). Similarly, increased risk was found when the TSB for HSD was <0.40 ($p = 0.029$), or between 0.93-1.47 ($p = 0.02$).

Discussion

The aim of this study was to use training and competition load metrics, derived from GPS, to investigate injury risk amongst elite youth and senior professional footballers at the same club. Specifically, the study investigated several independent variables including the training and competition duration; total distance covered; distance covered at high speeds; and the number of accelerations performed by the participants. The main findings of the study indicate that a limited number of the 'high' or 'very high' load variables predicted injury in this dataset, but that 'moderate', 'low' and 'very low' variables appeared to be more accurate predictors of injury. The other major finding was that the youth athletes had higher outputs in both volume (DUR & TD) and intensity (ACC & HSD) when compared to the senior athletes.

In line with previous research, the senior group's injury risk increased when the training duration TSB was 1.47-1.86. Although the previous research was conducted in cricket, it also found increases in injury risk when the TSB was >1.5 (Hulin et al., 2014). Similarly, in rugby league a TSB value of >1.5 was indicative of increased injury risk, however this was when the chronic load was high (Hulin et al., 2015). With the exception of training duration, the current study found no other relationships between high TSB scores and increased injury risk.

When considering high speed running distance, the results suggest that a TSB of 0.93-1.47 could result in an increased risk of injury in the youth athlete group. This is contrary to previous research which suggested that moderate TSB values ≤1.3 actually protected against injury (Gabbett, 2016; Malone et al., 2017; Windt & Gabbett, 2016). Gabbett (2016) described a TSB score of 0.8-1.3 as the 'sweet spot' in rugby league players, which was supported by the findings in the study by Windt and Gabbett (2016). This occurs where the acute and chronic loads are similar, thereby preventing the athletes from experiencing any peaks that their bodies are not conditioned to deal with. However, it should be noted that several injuries did occur in this study when the TSB was within the 0.8-1.3 'sweet spot' range, suggesting there is also some error in the model. Protective scores were also reported in football when the TSB was 1.00-1.25 (Malone et al., 2017). The study by Malone et al. (2017) was undertaken using senior athletes, but Foster, Wright, Battista and Porcari (2017) suggested that different risk factors are associated with injury in older athletes in comparison to elite youth athletes, such as reductions in $\dot{V}O_{2max}$ and lean muscle mass, together with increases in body fat. Reductions in $\dot{V}O_{2max}$ of approximately 7-12 % per decade appear to be common from the age of 20, regardless of activity levels (Hawkins & Wiswell, 2003). A study investigating the deconditioning in elite collegiate tennis players found $\dot{V}O_{2max}$ levels reduced from 53.9 ± 1.11 ml/kg/min to 47.86 ± 1.54 ml/kg/min over a 5 week period (Kovacs et al., 2007). This is possibly due to the reduction in blood and plasma volume leading to maximal and submaximal heart rates increasing (Mujika, Santisteban, Impellizzeri, & Castagna, 2009).

One study that did find similar results to the present one was that of Bowen et al (2016), which involved under 18 elite youth footballers. When using 'training load' as the variable, they found an increased risk of injury when the TSB was 0.88-1.31 (1.89 times more likely). It is logical to assume that certain variables are more relevant to different sports as there are physical differences in the basic skills required, such as a fast arm action in cricket, or covering longer distances at high speeds in football.

In the youth participant group it was found that an increased risk of injury was present when the TSB value for the high speed running distance was ≤0.4. These findings are similar to the study previously discussed and conducted in cricket, where it was found that when the TSB for the number of balls bowled was <0.49, the likelihood of injury was approximately 15 % compared to approximately 4 % when the TSB was 0.5-1.49 (Hulin et al., 2014). Gabbett

(2016) highlighted that undertraining is also detrimental to the athlete and can just as easily lead to injury due to a lack of appropriate preparation. It should also be noted that when the TSB is low, the chronic load will reduce and can lead to 1 of 2 outcomes; either a large spike in the acute load will occur, or the fitness levels of the athlete will decrease. If the acute workload is increased to prevent the chronic load from reducing, a high TSB will occur, which as previously highlighted, has been shown to increase the risk of injury (Hulin et al., 2015; Malone et al., 2017). Secondly, should the fitness levels drop too dramatically, the chance of injury is likely to increase due to the athlete not being able to tolerate the additional physical demands of the activity (Van Beijsterveldt et al., 2015). High
speed running places a significant strain on the hamstring musculature, which can lead to injury because of the excessive forces generated (Chumanov, Schache, Heiderscheit, & Thelen, 2012; Schache, Dorn, Blanch, Brown, & Pandy, 2012; Yu, Liu, & Garrett, 2017). During the swing phase, the hamstring must eccentrically contract to decelerate the extension of the knee and forward momentum of the lower segment of the lower limb (Yu et al., 2017). It is possible that a low level of high speed running prior to the injury may have deconditioned the hamstring musculature, exposing it to the risk of injury. This is in line with results from a study by Ekstrand et al (2009), who found that hamstring injuries were the most common type of injury with occurrence rates of 0.92/1000 hours. It would be useful for any future research to investigate the circumstances of the particular injuries, as this may provide a greater understanding to the mechanism of the injury.

When reviewing the classifications of the accumulated workloads derived from the Z scores, there was a noticeable difference between the two groups. The youth athletes completed 815 'high' and 55 'very high' periods; in comparison the senior athletes only completed 238 'high' and 46 'very high' periods. The position is reversed when considering the 'low' and 'very low' classifications, as here the senior athletes completed more 'low' and 'very low' periods than the youth athletes. The number of periods that were classified as ‘high’ in the youth group may explain why no significant increases in the injury risk were linked to high TSB scores. It has been demonstrated that high chronic loads were protective against any spikes in the acute loads (Bowen et al., 2016; Hulin et al., 2015). Bowen et al (2016) concluded their study by suggesting that the chronic load needs to be high enough to deal with spikes in the acute load, but must be prescribed in a manner that prevents the loads being the same. Otherwise this will result in training monotony, which occurs when the daily training routine becomes repetitive, and can lead to overuse injuries. It is also important to keep the chronic load high to allow the athlete to perform at the required level in competition, which, as highlighted earlier, is increasing in volume and intensity year by year (Barnes et al., 2014).

The youth athletes trained and competed for just over 8 hours per week on average in this study, which is less than the recommended 12 hours per week suggested by the Premier League (2011). This is comparable with research conducted in similar populations where the average training time per week over the duration of a season was 9.6 ± 2.9 hours (Noon, James, Clarke, Akubat, & Douglas, 2015). This figure, however, is still significantly higher than that of the senior athletes, and is so for all of the accumulated workloads. In the youth athletes, an increased risk of injury was found when the training duration was ‘very high’ (>25:15:00) in a 2-weekly accumulative period. It would be interesting to see if there was a difference if the sample size was larger. In the present study the senior athletes completed only 1 ‘high’ duration and no ‘very high’ periods; in comparison the youth athletes completed 75 ‘high’ and 2 ‘very high’ periods. If the senior athletes had completed the same number of ‘high’ duration periods, then it is possible that more injuries may have occurred, which would then have identified a relationship to injury risk.

When observing the total and high intensity distance covered, differences were noted between the two groups in the 2-weekly, 3-weekly and 4-weekly accumulative loads. An increased risk of injury was suggested in the senior athletes when a moderate total distance of 103800-138899 m was performed, or when a low high speed running distance of between 1705-5544 m occurred over a 4 weekly period. In comparison there were a higher number of periods where relationships were found in the classifications for the youth athletes. This suggests that the sample size was not the reason for the absence of a relationship in the senior athlete group, who participated in few ‘high’ and ‘very high periods, which may have led to the absence of any link to injury as previously discussed.

The study by Bowen et al (2016), found that the most significant predictor of injury occurred when a high number of accelerations were performed over a 3-weekly period. In comparison, this study found that a moderate number of accelerations performed over a 2-week period were significant. Bowen et al (2016), defined an acceleration as a change in speed of at least half a second, with maximum acceleration of at least 0.5 m/s^2. This study in comparison defined an acceleration as the number of increases in velocity above 3 m/s^2. Unfortunately not all GPS systems work in the same way and as different ones were used in these two studies, it is not possible to compare the results and decide whether or not a ‘low’ number of accelerations are equivalent. This is similar to the situation that occurred in the high speed running data, where Bowen et al (2016), define this variable as the distance covered ≥20 km/h, whereas in this study the threshold was lower as the GPS system used at the club had a fixed default ‘speed zone’ of ≥19 km/h.

Over a 1-week period, there was a correlation to the risk of injury in both studies where a ‘low’ number of accelerations were performed. It is possible that this may be due to a lack of prior conditioning. Acceleration has been shown to be an extremely demanding task, placing extensive forces on the body, and challenging for the neuromuscular system (Morin et al., 2015). The hip extensors, and specifically the hamstrings, play a pivotal role in acceleration. Athletes who can accelerate most successfully demonstrate the ability to generate high eccentric torque forces in the hamstrings, and pre-activate the muscle prior to contact with the floor at the end of the swing phase (Morin et al., 2015). Electromyography activity in the bicep femoris during the swing and end-of-the-swing phases, together with eccentric knee flexor peak torque are related to the amount of horizontal ground reaction force produced during acceleration. This is due to the backward "pawing" action of the leg just before contact with the ground (Morin et al., 2015). Ekstrand, Hagglund and Walden (2009) found that hamsting injuries were the most common in football. It is possible that the lower number of accelerations related to injuries in this study are due to the body not being conditioned for this highly demanding task, so that when a high intensity acceleration is performed the hamstring cannot tolerate the load. After 5 weeks of unsupervised training, reductions in acceleration, maximum velocity and power output were found in elite tennis players (Kovacs et al., 2007). This study also suggested that reductions in Type II muscle fibres can occur after only 2 weeks of deconditioning, which will account for the loss of physical capacity.

The frequency of injury in this study was significantly lower than research conducted on elite athletes at the highest level in European and Swedish football (Ekstrand et al., 2009; Malone et al., 2017). In those studies, the frequency of injury reported in competition was 8.7/1000 hours and 6.9/1000 hours, compared to 4.6/1000 hours in this study. The incidence of injury during training in this research was in between the values found in the other two studies cited above (4.6/1000 hours vs. 1.37/1000 hours and 4.9/1000 hours). When comparing the frequency of contact and non-contact injuries in the youth participants, this study reports a lower incidence in a similar population in both categories in comparison with the Bowen, et al (2016) study (non-contact 6.1/1000 hours vs. 6.9/1000 hours; contact 3.4/1000 hours vs.

5.2/1000 hours). Although there is a slight variance in the datasets, it is apparent that injury rates in football are significantly higher than other sports, even sports such American Football (4.4/1000 hours) and wrestling (2.5/1000 hours) where there is visibly more physical and high impact contact (Recher, Yard, & Comstock, 2008).

There are several limitations to the present study that may have affected the outcome. The TSB in this study was influenced by the football clubs' philosophy towards injury prevention, based on their understanding of the available research. Training load measures were reviewed on a daily basis to ensure that the individual loads were programmed to avoid high TSB values. This may have resulted in the absence of any relationships to injury in the study.

Similar to the other studies considering the TSB, this study did not take account of any 'off-field' training undertaken by the participants. One off individual or group training modalities such as gym sessions to develop strength and power, or additional work on a static bike or treadmill to develop aerobic/anaerobic capabilities were not recorded. This is potentially a deficiency in the study, as these factors can heavily influence the risk of injury due to the high stress and demands that can be placed on the musculoskeletal and neuromuscular systems. It is also more likely that senior athletes will have a higher training age in a gym-based situation, and as a result they will be better conditioned to tolerate the loads, which in turn will have less of an effect on field-based training and competition. Both the senior and junior players completed at least one individualised lower limb strength session, and one power based session per week. They also completed individualised injury prevention programmes on a daily basis. However, as it is hard to quantify such loads, this aspect of training load was intentionally omitted from of this study.

Other external factors can also influence the risk of injury and any physical outputs. One study considered the effects that recovery and stress can play in the role of injury prevention (Laux, Krumm, Diers, & Flor, 2015). The study used Recovery-Stress Questionnaires to assess the risk of injury in professional football players in Germany, with the results predicting injury to predominantly the lower limbs in the month after the assessment. This highlights the importance of frequent monitoring of recovery and stress to reduce injury risk (Laux et al., 2015). An athletes' perception of their own well-being can also have an effect on their performance level and injury risk (Noon et al., 2015). The participants in this study had several markers of well-being, fatigue and neuromuscular readiness to train recorded on a daily basis to assist in making informed decisions on training loads, and from that attempt to reduce the risk of injury. Due to the competitive nature of football it would be difficult to control all of the aspects that influence performance from every different club/study.

Hagglund et al. (2006) found that the best indicator of future injury was previous injury, with the risk of a further injury increasing 2-3 times in the following season if the player had sustained hamstring, groin or knee joint injury previously. Players were also 5.2 times more likely to suffer further injury if they had 5 or more previous injuries (Hagglund et al., 2006). Unfortunately, the injury history for a large proportion of the senior athletes at the club in question was not available due to the nature of football, where the players frequently move clubs in a short space of time, and for that reason it was not possible to include this within the study.

A further limitation of the present study was the 15-week duration of the data collection, which in comparison to other studies produced a limited sample size. Similar studies have collected data for a minimum of one full season and found significant differences when comparing data between the pre-season and competitive period (Bowen et al., 2016; Malone et al., 2017; Noon et al., 2015). The study by Malone et al. (2017) found that players who did not undertake high chronic workloads in pre-season were more likely to suffer an injury during the course of the competitive period. In a further study of rugby league players, it was found that lower training loads in pre-season significantly reduced the risk of injury, while still achieving the desired physical outcomes required to participate in the sport (Gabbett, 2004). The results of pre-season may also be influenced by players allowing their fitness levels to reduce to an unacceptable level during the off-season, and returning to training unprepared for the volume and intensity that is placed upon them in this period. Having regard to the above, the author is of the view that more relationships between high TSB and injury risk may have been present had the study covered a full 12-month calendar period.

Another potential shortfall in this study is that illness was not recorded. Other studies have found that high TSB were correlated with illness, possibly due to the increased demands placed on the body, causing the immune system to be suppressed. The addition of this data to the present study would have allowed a greater comparison with the other studies.

These findings suggest that all 3 hypotheses are rejected. The first hypothesis was that high TSB scores would predict injury in all participants. Only high TSB in one variable predicted injury in the senior athletes. The second hypothesis stated that high and very high accumulative loads would result in injury in all participants. This was accepted in part due to the very high training duration relating to injury in the youth participants, however there were no variables relating to injury in the senior participants. The third hypothesis stated that youth footballers would be exposed to a higher risk of injury due to the greater physical demands placed on them. Although this was partly accepted due to the high workloads undertaken by the youth participants compared to the senior participants, this had no bearing on the injury risk.

In conclusion, contrary to the findings in the previous studies referred to above, the present study found that high TSB values did not predict injuries in either the youth or senior participants. Furthermore, there was nothing to suggest that the higher workloads placed upon the youth athletes due to EPPP guidelines resulted in an increased likelihood of injury (The Premier League, 2011). Low loads appear to predict injury more significantly than high loads, possibly due to the athlete being unprepared for the physical demands of the sport.

One of the key objectives for the sports science team at the football club in this study is the prevention of injury. There is currently a greater understanding of the interaction of workload and injury risk than there has ever been, and the proactive approach adopted at the club is likely to have contributed to the low number of injuries that occurred, and also the results produced during this study. For that reason, a further study comparing two groups where one adopts a more 'traditional' approach to training and competition, with the other following a programme focusing more intensely on injury prevention could prove to be very revealing, and answer some of the questions posed by the results of this study.

Future research in the same area could also investigate how low loads affect the risk of injury. A larger sample size would also help to determine if there are any relationships. The inclusion of a number of different clubs where the approaches to training and competition differ will offer more weight to any findings across the sport as a whole. Unfortunately this may prove difficult to undertake due to a conflict of interest that exists between the clubs involved, who often have to compete against each other.

References

Barnes, C., Archer, D. T., Hogg, B., Bush, M., & Bradley, P. S. (2014). The evolution of physical and technical performance parameters in the English Premier League. *International Journal of Sports Medicine*, *35*, 1095–1100.

Blanch, P., & Gabbett, T. J. (2015). Has the athlete trained enough to return to play safely ? The acute : chronic workload ratio permits clinicians to quantify a player ' s risk of subsequent injury. *British Journal of Sports Medicine*, *0*, 1–5.

Bourdon, P. C., Cardinale, M., Murray, A., Gastin, P., Kellmann, M., Varley, M. C., … Cable, N. T. (2017). Monitoring Athlete Training Loads: Consensus Statement. *International Journal of Sports Physiology and Performance*, *12*, 161–170.

Bowen, L., Gross, A. S., Gimpel, M., & Li, F. (2016). Accumulated workloads and the acute : chronic workload ratio relate to injury risk in elite youth football players. *British Journal of Sports Medicine*, *0*, 1–8.

Chumanov, E. S., Schache, A. G., Heiderscheit, B. C., & Thelen, D. G. (2012). Hamstrings are most susceptible to injury during the late swing phase of sprinting. *British Journal of Sports Medicine*, *46*(2), 90.

Drew, M. K., & Finch, C. F. (2016). The Relationship Between Training Load and Injury , Illness and Soreness : A Systematic and Literature Review. *Sports Medicine*, 1–23.

Ekstrand, J., Hagglund, M., & Walden, M. (2009). Epidemiology of Muscle Injuries in Professional Football (Soccer). *The American Journal of Sports Medicine*, *39*(6), 1226–1232.

Foster, C., Wright, G., Battista, R. A., & Porcari, J. P. (2007). Training in the Aging Athlete. *Current Sports Medicine Reports*, *6*(3), 200–206.

Fuller, C. W., Ekstrand, J., Junge, A., Anderson, T. E., Bahr, R., Dvorak, J., … Meeuwisse, W. H. (2006). Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Scandinavian Journal of Medicine and Science in*

Sports, *16*, 83–92.

Gabbett, T. J. (2004). Reductions in pre-season training loads reduce training injury rates in rugby league players. *British Journal of Sports Medicine*, *38*, 743–750.

Gabbett, T. J. (2016). The training — injury prevention paradox : should athletes be training smarter and harder ? *British Journal of Sports Medicine*, *50*, 273–280.

Hagglund, M., Walden, M., & Ekstrand, J. (2006). Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. *British Journal of Sports Medicine*, *40*, 767–773.

Hawkins, S. A., & Wiswell, R. A. (2003). Rate and mechanism of maximal oxygen consumption decline with aging implications for exercise training. *Journal of Sports Medicine*, *33*(12), 877–888.

Hulin, B. T., Gabbett, T. J., Blanch, P., Chapman, P., Bailey, D., & Orchard, J. W. (2014). Spikes in acute workload are associated with increased injury risk in elite cricket fast bowlers. *British Journal of Sports Medicine*, *48*, 708–712.

Hulin, B. T., Gabbett, T. J., Lawson, D. W., Caputi, P., & Sampson, J. A. (2015). The acute:chronic workload ratio predicts injury: high chronic workload may decrease injury risk in elite rugby league players. *British Journal of Sports Medicine*, *0*, 1–7.

Jaspers, A., Brink, M. S., Probst, S. G. M., Frencken, W. G. P., & Helsen, W. F. (2017). Relationships Between Training Load Indicators and Training Outcomes in Professional Soccer. *Sports Medicine*, *47*, 533–544.

Kovacs, M. S., Pritchett, R., Wickwire, P. J., Green, J. M., & Bishop, P. (2007). Physical performance changes after unsupervised training during the autumn/spring semester break in competitive tennis players. *British Journal of Sports Medicine*, *41*, 705–711.

Laux, P., Krumm, B., Diers, M., & Flor, H. (2015). Recovery – stress balance and injury risk in professional football players: a prospective study. *Journal of Sports Sciences*, *33*(20), 2140–2148.

Malone, S., Owen, A., Newton, M., Mendes, B., Collins, K. D., & Gabbett, T. J. (2017). The acute: chonic workload ratio in relation to injury risk in professional soccer. *Journal of Science and Medicine in Sport*, *20*(6), 561–565.

Morin, J., Gimenez, P., Edouard, P., Arnal, P., Jiménez-reyes, P., Samozino, P., … Mendiguchia, J. (2015). Sprint Acceleration Mechanics : The Major Role of Hamstrings in Horizontal Force Production. *Frontiers in Physiology*, *6*(404), 1–14.

Mujika, I., Santisteban, J., Impellizzeri, F. M., & Castagna, C. (2009). Fitness determinants of success in men's and women's football. *Journal of Sports Sciences*, *27*(2), 107–114.

Noon, M. R., James, R. S., Clarke, N. D., Akubat, I., & Douglas, C. (2015). Perceptions of well-being and physical performance in English elite youth footballers across a season. *Journal of Sports Sciences*, 1–10.

Recher, J. A., Yard, E. E., & Comstock, R. D. (2008). An Epidemiologie Comparison of High School Sports Injuries Sustained in Practice and Competition. *Journal of Athletic Training*, *43*(2), 197–204.

Schache, A. G., Dorn, T. W., Blanch, P., Brown, N. A. T., & Pandy, M. G. (2012). Mechanics of the Human Hamstring. *Medicine and Science in Sports and Exercise*, *44*(4), 647–658.

The Premier League. (2011). Elite Player Performance Plan. London.

Van Beijsterveldt, A.-M., Stubbe, J. H., Schmikli, S. L., Van De Port, I. G. L., & Backx, F. J. G. (2015). Differences in injury risk and characteristics between Dutch amateur and professional soccer players. *Journal of Sports Science and Medicine*, *18*, 145–149.

Vigh-Larsen, J. F., Dalgas, U., & Andersen, T. B. (2017). Position specific acceleration and deceleration profiles in elite youth and senior soccer players. *Journal of Strength and Conditioning Research*, *Published*.

Windt, J., & Gabbett, T. J. (2016). How do training and competition workloads relate to injury ? The workload — injury aetiology model. *British Journal of Sports Medicine*, *0*, 1–9.

Yu, B., Liu, H., & Garrett, W. E. (2017). Mechanism of hamstring muscle strain injury in sprinting. *Journal of Sport and Health Science*, 1–3.

Appendices

Appendix A. Signed ethical approval letter

St Mary's University Twickenham London

13 January 2017 Unique Ref: SMEC_2016-17_051

James Walsh (SHAS): 'Predicting injury among older and younger elite soccer players using training load metrics'

Dear James
University Ethics Sub-Committee
Thank you for submitting your ethics application for the above research.
I can confirm that your application has been considered by the Ethics Sub-Committee and that ethical approval is granted.
Yours sincerely

Prof Conor Gissane
Chair of the Ethics Sub-Committee

Cc Dr Mark Waldron

Appendix B. Participant information sheet

Participant Information Sheet

'Predicting injury among older and younger elite soccer players using training load metrics'

You/ your child is invited to participate in a research study as part of an MSc dissertation. However, before you agree to take part/ allow your child to take part it is essential you understand what the study involves. Please spend time reading this document and do not hesitate to ask any questions you may have.

Purpose and value of the study

The purpose of the study is to look at how injuries may be predicted in football by looking at training load data collected from GPS and Heart Rate scores during training and games. Data will be analysed to see which, if any, variables predict injury most accurately. The data will then be further analysed to determine if there are any differences in predicting injury between younger and older players. Any variables that are found to significantly predict injury may be used in professional practice in order to reduce injury rates.

Who is organising the research?

The research is organised by a MSc student and overseen by an academic dissertation supervisor. The MSc student is also employed full time by Doncaster Rovers FC as the Head of Academy Sport Science. An ethics committee have also given permission for the research to go ahead.

What will happen to the results?

The results will be published as part of an MSc dissertation and potentially presented at a conference or published in a peer reviewed journal.

Source of funding for the research

There is no funding required for this research.

Contact for further information

James Walsh
St Marys University
Waldergrave Road
Twickenham
TW1 4SX
Email: 135482@live.stmarys.ac.uk

Why have you been invited to take part in the study?
You are an elite footballer who is a player at the club where the research is going to be conducted

Do you have an option to refuse to take part?
You are not obliged to take part in the study. You may also withdraw from the study at any point

What do you need to do?
You do not need to change any daily activities you currently do. You are required to wear your GPS/Heart rate monitors for all training sessions and games. You will need to give no time up for the study other than completing consent forms

What are the risks and should any special precautions be taken?
There are no risks other than the usual risk of injury that is present when playing football

Will agreeing to participate in the research compromise your legal rights?
No your legal rights are not comprimised should something go wrong

What will happen to your data?
Your data will be used to complete a MSc dissertation. Your data will only be made public as part of an average score. Data is stored securley on a password protected computer on a secure server. Doncaster Rovers FC may get an anonymised summary of findings which could enable better prediction/avoidance of injury.

What benefits will you receive?
No financial reward is given for participation in the study

YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP TOGETHER WITH A COPY OF YOUR CONSENT FORM

Appendix C. Participant consent form

St Mary's University Twickenham London

Name of Participant: ____

Title of the project: Predicting injury among older and younger elite soccer players using training load metrics

Main investigator and contact details: James Walsh
135482@live.stmarys.ac.uk

Members of the research team: Dr Mark Waldron

1. I agree to take part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what my role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information I provide will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.
6. I agree to the use of my injury data for the purpose of research.

Data Protection: I agree to the University processing personal data which I have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of participant (print)……………………………………………………………………..
Signed…………………..…………………
Date……………………………........

If you wish to withdraw from the research, please complete the form below and return to the main investigator named above.
Title of Project: Do the key indicators for predicting injury differ between elite youth and senior professional footballers?

I WISH TO WITHDRAW FROM THIS STUDY
Name:____

Signed: ________________________________ Date: ____________________

Appendix D. Parental consent form

St Mary's University Twickenham London

Name of Participant: ____

Title of the project: Predicting injury among older and younger elite soccer players using training load metrics

Main investigator and contact details: James Walsh
135482@live.stmarys.ac.uk

Members of the research team: Dr Mark Waldron

1. I agree to my child taking part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what my child's role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw my child from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information I and my child provides will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.
6. I agree to the use of my childs injury data for the purpose of research.

Data Protection: I agree to the University processing personal data which I and my child have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of parent (print)……………………………………………………………………………..

Signed………………..………………… Date…………………………..........

If you wish to withdraw your child from the research, please complete the form below and return to the main investigator named above.

Title of Project: Do the key indicators for predicting injury differ between elite youth and senior professional footballers?

I WISH TO WITHDRAW MY CHILD FROM THIS STUDY

Name of Participant: ____

Name of Parent ____

Signed: ______________________________ Date: __________________

Appendix E. Company consent letter

Doncaster Rovers
Football Club

CLUBDONCASTER

To whom it may concern;

I am writing on behalf of Doncaster Rovers Football Club. I, Kieran Scarff, am the Academy Manager at the club and responsible for all the junior players at the club. I give permission for James Walsh to use data that he collects for the purpose of his MSc thesis. He may collect data using GPS and Heart Rate systems and also through verbal communication. He has permission to use players from our under 18 squad (scholarship players).

Regards

Kieran Scarff

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